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6. AUTHOR(S)
Kenneth J. Wynne, Ph.D.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Virginia Commonwealth University
School of Engineering
PO Box 843068
Richmond, VA 23284-3068

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Office of Naval Research
Program Officer, James P. Armistead
ONR Code 331
Ballston Center Tower One
800 N. Quincy St., Arlington, VA 22217

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The goal for this project was to establish feasibility for a surface modifying additive concept whereby the surface of coatings could be made antimicrobial. Proof of principle was established via the synthesis and testing of a generation 1 (Gen-1) polyurethane antimicrobial surface modifying additive that killed challenges of *P. aeruginosa* (Gram negative) and *S. aureus* (Gram positive) in 30 minutes or less.

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Protection Against Pathogens via Biocidal Polymers

PI: Kenneth J. Wynne, Professor
Chemical Engineering, Virginia Commonwealth University
Richmond, VA 23284-3028
Ph: 804-828-9303, Fax: 804-828-3846, e-mail: kjwynne@vcu.edu

Summary: The goal for this project was to establish feasibility for a surface modifying additive concept whereby the surface of coatings could be made antimicrobial. Proof of principle was established via the synthesis and testing of a generation 1 (Gen-1) polyurethane antimicrobial surface modifying additive that killed challenges of *P. aeruginosa* (Gram negative) and *S. aureus* (Gram positive) in 30 minutes or less.

Objective: The objective of this project was to establish feasibility for a new concept for antimicrobial coatings. The goal was to establish feasibility for a new concept whereby a surface modifying additive provided a nanoscale delivery vehicle by which coating surfaces could be made antimicrobial.

Approach: The approach focused on generating a polyurethane surface modifying additive (SMA). The elements of this SMA are shown in Figure 1. These include (1) the surface modifying additive is a small percentage of the whole so that only the surface is modified (not bulk properties) (2) The SMA is a polyurethane which is comprised of a hard block and a soft block, (3) The soft block is functionalized as the soft block tends to be surface active, (4) the soft block has (a) a surface active group that acts as a "nanobaloon" to bring (b) the biocidal function to the surface.

By the SMA concept, the additives have a nanostructured designed that can be tailored to optimize function. In theory, the SMAs is thermodynamically driven to the surface during conventional coating and molding processes. Secondly, the SMAs have a nano-component that locks the SMA to the commodity polymer thus avoiding phase separation (bleeding, scaling). Additional modification was

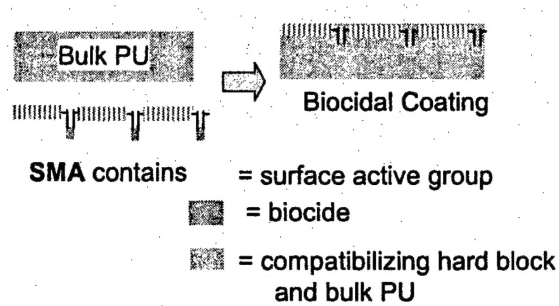

Figure 1. Schematic of the biocidal surface modifying additive (SMA) concept

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anticipated to provide characteristics such as wetting modification or specific interactions with target organisms. This nanostructured SMA approach avoids degrading bulk mechanical properties of the commodity polymer.

<u>Results</u>: For proof of principle we chose to generate a polyurethane SMA, as polyurethanes are widely used in military coatings and apparel. To implement this new approach to biocidal polymers, we focused on the synthesis of surface active biocidal "soft blocks" for polyurethanes (PUs), as the low T_g soft block dominates the surface in coatings or moldings. We prepared a first generation (Gen-1) SMA-PU with a soft block containing a fluorinated (air-philic) group and a biocide. The structure is shown in the upper part of Figure 2. Adding the Gen-1 SMA-PU (2%) to a base PU (98%) resulted in optically transparent coatings. Dynamic Contact Angle (DCA) analysis provided evidence for the surface activity in air and water of this SMA-PU. A modified Modified AATCC-100 "sandwich" test developed in collaboration with the VCU School of Medicine, Department of Microbiology and Immunology (Dr. Dennis Ohman, Chair and Dr. Lynn Wood). Challenged with *Escherichia coli* the Gen-1 (2%) coating effected 8-log reduction of bacteria in 30 minutes. This sets a lower limit in biocidal activity as all (1 x 10^8) *E. Coli* bacteria were killed.

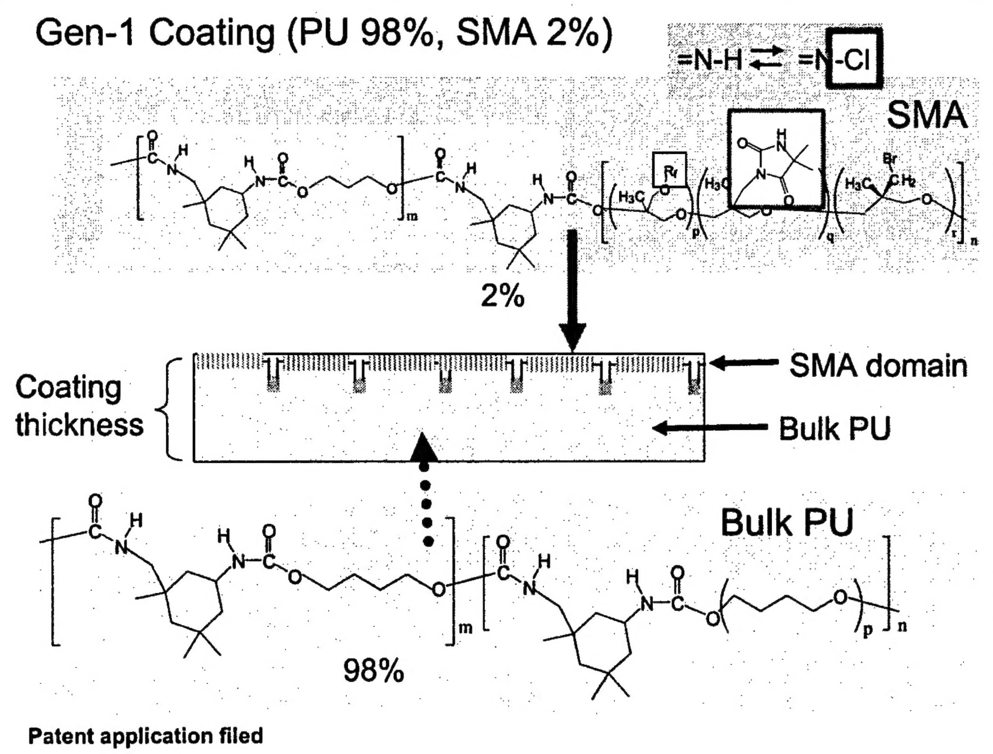

Figure 2. Structure of our successful biocidal SMA and schematic of the SMA coating implementation.

Subsequently it was shown that Gen-1 SMA 2% in a base polyurethane coating effectively killed challenges of *P. aeruginosa* (Gram negative) and *S. aureus* (Gram positive). The exposure time was reduced to 15 min in an initial attempt to know "kill kinetics". For *P. aeruginosa*, 100% kill was observed in 15 min for the Gen-1 (2%) PU coating. Against *S. aureus*, 30 min was required for 100% effectiveness.

Success with the Gen-1 SMA has led to current synthesis, processing, and testing of a Gen-2 coating under DARPA support.